

DOCUMENT RESUME

ED 196 898

SP 017 386

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TITLE Public Schools Should Learn to Ski...And Other
Helpful Hints for Educating in the 21st Century.
PUB DATE Jan 81
NOTE 10p.: Paper presented to the National Curriculum
Study Institute (Phoenix, AZ, January 12-13,
1981).
EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Behavioral Objectives; *Cognitive Style; Competency
Based Education; Computer Assisted Instruction;
Curriculum Development; Elementary Secondary
Education; Humanistic Education; *Individualized
Instruction; *Learning Modules; *Programed
Instruction; Student Characteristics; *Student
Motivation; Time Factors (Learning)

ABSTRACT

Due to the different rates of learning expressed by greatly differing students, a recent educational trend has developed that responds to different learner needs through the introduction of programed or individualized instruction. The consequence of the use of instructional packets is that the learners must frequently teach themselves while following the instructions, thereby removing contact between teachers and students. In response to this problem, a "human" system has been developed which permits students to learn and gain mastery of knowledge at various rates. Instruction in this system is highly focused since instructional groups are formed around specific learning objectives or outcomes. Students can work together with teachers, interacting in a very human and responsive way. Teachers are able to use a greater variety of tailor-made materials and methodologies. However, since students inevitably learn at different rates, management tools have to be built into the system permitting the flexible reorganization of instructional groups on a continuous basis. (JN)

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PUBLIC SCHOOLS SHOULD LEARN TO SKI...

and other helpful hints for educating in the
21st century

by

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a presentation at the

NATIONAL CURRICULUM STUDY INSTITUTE

A.S.C.D.

January 12-13, 1981

Phoenix, Arizona

U.S. DEPARTMENT OF HEALTH,
EDUCATION & WELFARE
NATIONAL INSTITUTE OF
EDUCATION

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I am a tool-maker. Eighteen years ago I received a Ph.D. in the field of General Systems Research. I was fortunate enough to participate in a unique doctoral program and was trained by leading mathematicians, socialologists, economists, computer scientists, and cognitive theorists to construct problem-solving "tools" that were applicable to problems in many fields.

Fifteen years ago, I began to develop various educational tools to solve problems not only faced by educators in the public elementary and secondary schools, but ones that were being confronted in all learning situations (industrial training programs, training programs for the defense department, and programs at the university and professional graduate school level: medicine, dentistry, architecture, etc.). The problems were fundamental "school" problems such as, "How does an educational institution provide for students who learn at different rates and, therefore, always have widely differing learning needs because of differences in ability, past experiences and levels of motivation?" These problems occur in all school and learning situations...not just in public school classes. In other words, the "tools" I have been developing were designed to be applicable in many different educational situations.

The first "tool" I developed and will discuss is a "cognitive map or hierarchy." It isn't simply limited to the elementary school mathematics program I will describe, although this is where it had its genesis and where it first proved itself. This same "tool" can be used in hundreds of learning situations and is applicable to many curriculum areas at many different levels (elementary school through graduate school and industrial training settings).

DIFFERENT RATES OF LEARNING

Educators, at all levels and in all fields, have long recognized that learners learn at widely differing rates according to real and observable differences in their abilities, previous experiences, and motivation to learn. These differences inevitably place learners at different points along any learning continuum and present educators with the challenge of trying to respond not only to different but to ever changing needs of many learners. In effect, each learner in a class always seems to need something else at each given moment...and there is but one teacher with one pair of hands!

Recently, in frustration and in an effort to respond to these many different learner needs, publishers and educators alike have moved to introduce "programmed and/or individualized instruction." The general intent of each of these programs is to place a unique instructional packet (folder, card, prescription, module, cassette, computer disk, etc.) onto the desk and into the hands of each learner. However, the consequence of such programs is frequently to ask the learner to "teach himself" by following the instructions contained in his "learning packet." While this method does indeed respond to the range of learning needs characteristic of any group, it does so at the cost of removing teachers from students and students from each other. Now, packets frequently teach students...not teachers. Teachers complain they have "lost touch" with their students...students are described as bored and unmotivated...and parents decry a system where teachers no longer teach their kids!

In response to this problem, I developed a human SYSTEM composed of a number of parts or "tools." Together, these "tools" form an educational system that permits and encourages students to learn and to gain mastery of knowledge and skills at different and unique rates.

HIGHLY FOCUSED INSTRUCTION

Instruction in this system is highly focused and efficient since instructional groups are formed around specific learning objectives or outcomes. All students, in any of the assembled classes, "need" just about the same instruction at the same time. Students are also ready and able to learn the new objective since these students not only share a congruent need to learn this objective, all have also met the prerequisites necessary for learning the objective. Teachers can zero-in on the needs of the students in such a group since the range of these learning needs is highly restricted and limited. Kids can work together and with their teacher, interacting in a very human and responsive way, rather than being directed to some non-human "thing" called a "Individualized Instruction Packet." Teachers, therefore, are much more able and likely to use a wide variety of tailor-made materials and methodologies - adjusting them to individual learning styles - since, with a restricted range of learning needs, the teacher can realistically focus on other considerations.

"Gifted" kids move as quickly as they need to in such a system. "Learning Disabled" kids don't get pushed along in confusion. Neither of these students is segregated or separated into a different program. Kids in both of these groups learn and move, albeit at different rates, within the same structure and the same system. (The system is thus far more efficient, fiscally responsible, and dollars go a lot further!)

However, since students inevitably learn at different rates, management "tools" have to be built into the system permitting the flexible reorganization of instructional groups on a continuous basis. (Past experience shows us that approximately fifteen percent of the students participating in such a learning system should and will need to be re-evaluated and may move into a new instructional group on a daily basis.)

MAPPING THE ROAD TO LEARNING

The first of these "management tools" I developed was a "Cognitive Hierarchy" (see attached). A hierarchy is a conceptual tool borrowed from the taxonomists and mathematicians working in disciplines such as cybernetics, engineering, and management theory. It is simply a "map" that graphically displays all of the steps, routes, and sequences, in a particular field of knowledge. While this particular hierarchy reveals the steps and sequences and reflects how mathematics is learned - from a nursery school level through high school Algebra - it is possible to develop other maps that graphically chart the development of almost all other areas of knowledge.

Each circle in the hierarchy represents a limited and operationally well-defined set of learning objectives or outcomes. For example, the circle coded "F8," represents "the ability to add fractions using both similar and dissimilar denominators."

For each circle or learning-based outcome, there is a corresponding test or means of evaluating the outcome and, since there are both verbal and non-verbal outcomes in the program, there are both verbal and non-verbal methods of evaluation built into the program.

Each line of tangency connecting two circles communicates a relationship of dependency

(super-ordinate/sub-ordinate). Circles that are "above" one another are super-ordinate while circles "below" are sub-ordinate. In other words, since a line connects F7 to F8 and F8 is "above" F7, we can say there is a dependency relationship and that F7 is an objective that must be learned first.

STATISTICAL VALIDATION

The math hierarchy is not speculative. The relationships between the various circles, representing specific objectives or learning-based outcomes, have been rigorously tested and have now been validated. The value of any hierarchy depends upon its statistical validation (significant at the .01 level). For example, given such a validated relationship, we would certainly want to be certain that the student had F7 knowledge before we attempted to teach him - or expected him to learn - F8. However, it is also evident from examining the hierarchy, that F8 has another prerequisite, namely D8. In other words, before a student is "able and ready" to learn F8, the hierarchy tells us he must first have both F7 and D8 knowledge.

These line relationships within the hierarchy know no geographic or socio-economic bounds. In order to learn F8, you must know F7 and D8 whether you attend school in an affluent suburban district, in a poor urban ghetto, in the northern part of the country, or in the south. Conversely, once a student has learned F7 and D8, he can learn F8 with relative ease and within a reasonable amount of time (defined by a normative time range for each objective) regardless of where he goes to school...if he is taught it! Many a student who appears to "get stuck" at some point in a math program - or in any other course - may not be "inept," "lazy," or "unmotivated," or a "slow learner." She or he may simply lack the critical prerequisite knowledge. If we can pinpoint with scientific exactness, "What must come before what," we may be able to take some of the bumps out of the road.

HOW IS A HIERARCHY VALIDATED?

A hierarchy is never constructed from "scratch." The development and validation of a hierarchy initially entails organizing the experiences and observations of many teachers into a set of assumptions and hypotheses which are then subjected to testing.

The lines in this Math Hierarchy were initially drawn by making assumptions about which objectives were dependent upon which others. Each of these lines of dependency was validated after first testing many students and establishing a three-to-five-year data base. The data was then analyzed, using a computer generated "cross-matrix factor analysis." Approximately thirty million pieces of data were analyzed in the first validation study. The lines you now see drawn on this hierarchy emerged from that study. They are no longer guesses. We now know that in order to learn F8, the student has to first learn F7 and D8.

THE USEFULNESS OF HIERARCHIES

An empirically validated hierarchy can be used in a variety of important ways:

1. As a student profile

Each student helps to maintain his own profile (hierarchy). As additional knowledge is gained over a period of time, new circles are colored-in in a continuing process of "color-me-competent."

Circles are color-coded according to time so that at each moment the hierarchy displays what knowledge the student has, when that knowledge was attained, and what knowledge the student does not yet possess.

Thus, on one 8 1/2 by 11 sheet of paper, the history of a student's mathematical development ranging from Kindergarten through high school Algebra, can be recorded and displayed. It is a compact and visually graphic information system that can be very useful to students, parents, and all teachers and other school personnel that will work with the student over a period of years.

2. Record-keeping

The hierarchy is also at the heart of an efficient record-keeping and data collecting system that can be used to supplement the individual profiles. Supplementary data is written and appended to each student's hierarchy. For each objective additional information includes:

- a) the day the student began working on the objective -
- b) the day he completed work -
- c) the score(s) on all criterion referenced tests -
- d) the name of the teacher -
- e) a qualitative rating or assessment for his work on that objective and for that period of time.

This supplementary information is generally proved most useful at times of parent/student conferences and during formal written reporting periods.

3. Management, Organization and Computer applications

We have organized and managed this program for the past 15 years using a number of simple graphic displays. No computer has been involved in the operational management of the program. However, to facilitate a number of administrative and management objectives, I have recently created a series of computer programs designed to be used on "the garden-variety type" of personal microprocessing computer now bursting onto the market (Apple II, Radio Shack TR5-80, PET, Atari, etc.). These programs have been written on floppy-disks and are designed to use with a two (2) DOS system...in other words, a relatively inexpensive system economically within reach for most schools/systems.

As before with hand-written individual student records, the computer program can also store (and display) information about individual students, including:

- a) What objectives each student had mastered at the time of entry into the school and system -
- b) What new objective(s) each masters -
- c) How long it takes for each new objective to be mastered by each student -
- d) The name of the teacher responsible for each objective -
- e) The score(s) each student obtains on each criterion reference test(s) -

However, in addition to these functions, the computer programs were written to assist with many administrative and management tasks and to create a whole new range of decision-making opportunities based upon the hierarchy. Most importantly, the new computer programs make it possible for schools and other education institutions to better address the original problems:

- "How can a school most effectively organize its programs to accommodate the wide range of student differences and learning needs?"
- "How can this be done without substituting "learning packets" for teachers?"

A SKI SCHOOL ANALOGY

It is probably easier to understand how these organizational goals are met by using a familiar analogy. Conceptually, the way in which Ski Schools are organized is the model closest to an understanding of how this type of "system" operates (now with the aid of a computer) to accommodate the wide range of learner differences. Ski Schools organize each of their instructional groups based on two common characteristics:

1. Everyone in an instructional group shares a common need to learn the same thing, at the same time, and the group is formed around that specific skill, objective, or outcome (eg. the need to learn "snow-plow turns").
2. Everyone in an instructional group has already mastered the objective(s) the Ski School knows is (are) prerequisite to learning this new objective (eg. "snow-plow stops").

All other student characteristics may vary. The skiers may vary in age, ability, previous experience, socio-economic level, motivation, etc. All these factors may affect the rate at which they will subsequently learn but, at this given moment, they are all placed into the same learning group because they all need to learn the same thing. When that no longer is true because someone learns something new, that person will be re-deployed to a new group on a new slope to learn something else.

Transferring this analogy to a school and to our system, we also organize instructional groups around some common characteristic where students share a congruent learning need. We might thus set up an "F8" instructional class to teach kids, "How to add fractions." The criteria for which students we would include in such a group would be:

- The student has not yet mastered "F8"
- The student has mastered "F7" and "D8," the objectives that we now know are "pre-requisite" and necessary to learn before "F8" can be learned... so says our hierarchy or road map!

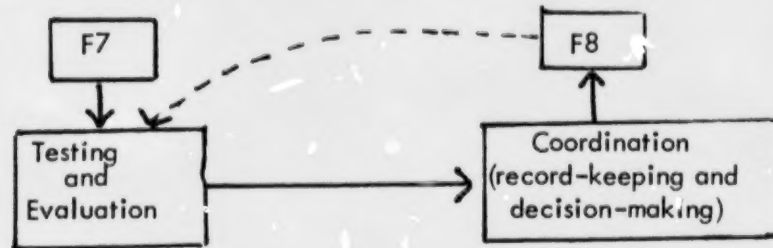
The computer programs I have created are now able to organize such instructional groups, literally with the "touch of a button!" The entire hierarchy has been programmed. In effect, the computer continuously searches each individual student's history and prints out an "Eligibility" list containing only the names of those students who share a common instructional need. When the group is formed around this learning outcome, the teacher can work with the students as a group, and the students can meaningfully interact with each other since each is working toward mastery of the same goal. Instructional Nirvana!

DIFFERENT RATES OF LEARNING

Yet, even when students all start out with the same instructional needs - whether in a math class or on the slopes - "learning" and individual mastery will occur at very different times according to individual differences in ability, experience and motivation. Therefore, any "good" learning system must be flexible enough to accommodate the different rates at which people learn.

On the slopes this is done quickly, continuously, and effectively. As individual skiers develop proficiency at the objective around which the group was formed, the skier is re-evaluated. If he meets the clearly defined criteria for mastery, he is sent back to "ski headquarters" for re-deployment and re-assignment to another instructional group where he will once again be working toward mastery of a new goal, this time within a new group. He might be assigned to any one of several groups for which he is eligible but, in each case, the group will be working on an objective he has not yet mastered (but one within his ability to master because he will have the necessary pre-requisites).

In our system, we also accommodate the different rates at which students learn just as quickly, continuously, and effectively. When a student appears to have "learned," he, too, is re-evaluated and, if mastery has taken place, he will be re-assigned to another instructional group that is now appropriate for his new instructional needs. Any group is considered "appropriate" if he has not yet mastered this new objective but has demonstrated mastery of the necessary pre-requisite objectives.



RESULTS

This program has been in operation at Center School in New Canaan, for the past 15 years. With approximately 400-500 students annually in the program, new program decisions are made daily for approximately 60-80 students. In contrast to many learning situations where a student is assigned to a "ability grouped" "top, middle, or bottom" group for the year - and frequently, therefore, for his school career once he is "tracked" - approximately 15% of the students are reorganized into new instructional groups each day. Each decision is unique and is made individually. Each responds to the changing instructional needs of individual students learning at individual rates. And, it is all done with amazing ease!

It works and it works well! Based upon standardized testing of both intelligence and achievement, students have consistently achieved higher achievement scores than would be predicted on the basis of intelligence scores. During each of at least the last five years, the median achievement score at the sixth grade level has been within two months of the maximum score possible on the

standardized test. Not one child in the entire school is scoring below grade level expectations. On average, 10% (or more) of each year's sixth grade have and will pass the Algebra 1 examination published for high school students by Educational Testing Service.

Today, teachers operate with high morale, working closely together as part of a system where the accountability for each student's progress is placed on the "system" rather than upon the shoulders of individual teachers. When confronted with a problem in the past, many teachers frequently turned to point an accusing finger at the student's previous teacher. And, if last year's teacher couldn't be "fingere," the finger was frequently re-directed at the student's "poor family background," the only other plausible reason why learning was not taking place. Trying to fix individual accountability and place blame often proves counter-productive. Rather, we have tried to build a cohesive system of well-defined inter-dependent relationships, roles and expectations, consistent with the needs of the program and of the individual human beings that work together within it.

Kids like math. Mothers are even happy!

